**PMS 509 Knowledge Technologies**
**Homework II**
**Due on December 20, 2018.**

1. Consider the following RDF graph $G$:

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix ex: <http://middle-earth.org/> .

ex:Thorin rdf:type ex:Dwarf .
ex:Thrain rdf:Type ex:Dwarf .

ex:Thorin ex:hasFather ex:Thrain .
ex:Thrain ex:hasFather ex:Thor .

ex:Thorin ex:hasTitle "King under the Mountain" .
```

   Express the query "Find all the dwarfs, their fathers and optionally their title" using the algebraic formalism of the paper

   > Jorge Perez, Marcelo Arenas, and Claudio Gutierrez. *Semantics and Complexity of SPARQL*. Proceedings of ISWC 2006.

   which we discussed in class and it is available at `http://marenas.sitios.ing.uc.cl/publications/iswc06.pdf`. What is the answer to this query? Show all the steps of its evaluation using the algebra developed in the paper.

   **(30 marks)**

2. "Translate" the following Greek sentences into $\mathcal{ALCQO}$. If you think that the given sentence cannot be translated into $\mathcal{ALCQO}$, then you should give a translation into first-order logic (remember: $\mathcal{ALCQO}$, like all DLs we studied, is a subset of first-order logic).

   (α′) Όλοι οι φοιτητές είναι έξυπνοι.
   (β′) Υπάρχει ένας φοιτητής.
   (γ′) Υπάρχει ένας έξυπνος φοιτητής.
   (δ′) Κάθε φοιτητής συμπαθεί ένα φοιτητή.
   (ε′) Κάθε φοιτητής συμπαθεί ένα άλλο φοιτητή.
   (ϛ′) Υπάρχει ένας φοιτητής που τον συμπαθούν όλοι οι άλλοι φοιτητές.
   (ζ′) Ο Γιάννης είναι φοιτητής.
   (η′) Ο Γιάννης δεν παίρνει το μάθημα της Τεχνητής Νοημοσύνης.
   (θ′) Κανείς φοιτητής δεν συμπαθεί τον Γιάννη.
   (ι′) Ο Γιάννης έχει τουλάχιστον μία αδερφή.
   (ια′) Ο Γιάννης δεν έχει αδερφή.
   (ιβ′) Ο Γιάννης έχει το πολύ μία αδερφή.
   (ιγ′) Κάθε φοιτητής παίρνει τουλάχιστον ένα μάθημα.
   (ιδ′) Μόνο ένας φοιτητής απέτυχε στον μάθημα της Τεχνητής Νοημοσύνης.
   (ιε′) Κανείς φοιτητής δεν απέτυχε στο μάθημα της Τεχνητής Νοημοσύνης αλλά τουλάχιστον ένας φοιτητής απέτυχε στο μάθημα των Βάσεων Δεδομένων.

(ιϛ′) Κάθε φοιτητής που παίρνει Τεχνητή Νοημοσύνη, παίρνει επίσης Λογικό Προγραμματισμό.

(ιζ′) Κανείς φοιτητής δεν μπορεί να ξεγελάσει όλους τους άλλους φοιτητές.

(ιη′) Δίποδο είναι ένα ζώο με ακριβώς δύο πόδια.

(ιθ′) Τρίγωνο είναι ένα πολύγωνο που έχει ακριβώς τρεις γωνίες και ακριβώς τρεις πλευρές που είναι ευθύγραμμα τμήματα.

(κ′) Ορθογώνιο τρίγωνο είναι ένα τρίγωνο που μία από τις γωνίες του είναι ορθή.

**(40 marks)**

3. Which of the following expressions are syntactically correct in $\mathcal{ALCQ}$ and which ones are incorrect?

   (a) $\texttt{Person} \sqcap \texttt{hasChild}$

   (b) $\exists\texttt{hasChild}. \equiv \texttt{Person}$

   (c) $\exists\texttt{hasChild}.(\geq \texttt{1})$

   (d) $\texttt{hasChild} \sqsubseteq \texttt{hasBaby}$

   (e) $\texttt{hasChild}(\texttt{ANNA})$

   (f) $\texttt{Person} \equiv \exists\texttt{hasChild}.\bot$

   **(6 marks)**

4. Consider the following English sentences:

   - Yannis is a person.
   - The only kind of coffee that Yannis drinks is frappe.
   - A Greek is a person who drinks only frappe coffee.[1]
   - Yannis is Greek.

   Now answer the following questions:

   (a) Give an $\mathcal{ALC}$ knowledge base $KB$ which formalizes the first three of the above sentences and an $\mathcal{ALC}$ formula $\phi$ that formalizes the fourth sentence.

   (b) Construct an interpretation $\mathcal{I}$ which satisfies $KB$.

   (c) Construct another interpretation $\mathcal{I}_1$ which does not satisfy $KB$.

   (d) Use tableau techniques to prove that $KB \models \phi$. Your proofs in this and following exercises must be very detailed (in particular, formulas participating in a proof must be numbered so that the application of each rule clearly shows what formulas are involved).

   **(10+5+5+10=30 marks)**

5. Consider the following English sentences (a more involved version of the previous example):

   - Yannis is a person.
   - Frappe is a kind of coffee. Nescafe frappe is a kind of frappe.
   - The only kind of coffee that Yannis drinks is Nescafe frappe.

[1] I admit that this is a rather short-sighted definition!

- A Greek is a person who drinks only Frappe coffee.
- Yannis is Greek.

Now answer the following questions:

(a) Give an $\mathcal{ALC}$ knowledge base $KB$ which formalizes the first four of the above sentences and an $\mathcal{ALC}$ formula $\phi$ that formalizes the fifth sentence.

(b) Use tableau techniques to prove that $KB \models \phi$.

This proof involves dealing with arbitrary TBoxes, not just TBoxes with acyclic terminologies that we covered in the lectures. There is an extra transformation rule that you will need in this case. The details are given in the following paper we have in the readings: "Franz Baader. Description Logics. In Reasoning Web: Semantic Technologies for Information Systems, 5th International Summer School 2009, volume 5689 of Lecture Notes in Computer Science, pages 1-39. Springer-Verlag, 2009." It is available from `http://lat.inf.tu-dresden.de/research/papers.html`.

**(10+30=40 marks)**

6. Consider the following English sentences:

   - Walt is a person.
   - Walt has three distinct pets: Huey, Dewey and Louie.
   - Huey, Dewey and Louie are animals.
   - An animal lover is a person which has at least three pets that are animals.
   - Walt is an animal lover.

   Now answer the following questions:

   (a) Give an $\mathcal{ALCQ}$ knowledge base $KB$ which formalizes the first four of the above sentences and an $\mathcal{ALCQ}$ formula $\phi$ that formalizes the fifth sentence.

   (b) Use tableau techniques to prove that $KB \models \phi$.

   The description logic $\mathcal{ALCQ}$ has been covered in class. The tableau proof techniques for it have not been covered in class but are covered in the paper by Franz Baader cited above.

   **(10+30=40 marks)**

7. In the file `family-homework3.owl` that will be provided to you, you will find an ontology of human families expressed in OWL 2 (RDF/XML syntax). Using Protege, you should answer the following questions:

   (a) Study the ontology carefully and propose any re-organization of it that will make it better (i.e., make it capture the domain of interest in a more precise way given the expressive power of OWL 2). The ontology scope must remain the same (i.e., you should not define entirely new family concepts or properties in the ontology e.g., cousin or age). In this part of the exercise, you should consider only classes and properties; do not worry about individuals.

(b) Now populate the ontology with all (and only) the individuals of the British Royal Family, House of Windsor (1917-today) presented on the Web page: `http://www.britroyals.com/windsor.htm`.[2] Some individuals already exist in the ontology just to give you a start, but no effort has been made to add them fully to the ontology. This is your job.

(c) Now add to the ontology appropriate axioms, so that the following domain concepts are introduced and related correctly with the concepts existing already: grandfather, grandmother, grandparent, ancestor, uncle, aunt, cousin and second cousin.

(d) Now use the DL-Query Menu of Protege 4 to express the following queries. If there are any queries that you cannot express, you should explain carefully why this is the case.

- Find fathers with more than 2 male children.
- Find people with more than 1 marriage.
- Find people that are not alive today.
- Find cousins of Prince William.
- Find people that have children that have an age difference of at least 10 years.

**(80 marks)**

[2] I couldn't find a more exciting example! You might need to go other Web pages to find details e.g., missing dates of marriages etc. But do not add information that is not required by the ontology!